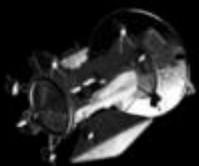


“...oh brave new world...”

Titan/Saturn System Mission 2008: Exploring Titan on a Budget (*and Without Aerocapture!*)

Tom Spilker, John Elliott, Kim Reh, Nathan Strange
Jet Propulsion Laboratory, California Institute of Technology
Jonathan Lunine
Lunar & Planetary Laboratory, University of Arizona





➤ *Dedicated Titan orbiter with accommodation for ESA in situ elements*

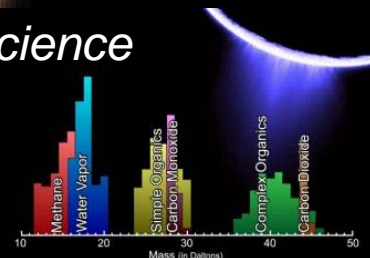
➤ *Enceladus science and Saturn magnetospheric interaction with Titan*



➤ *Advancement in understanding Titan well beyond the high bar set by Cassini-Huygens*



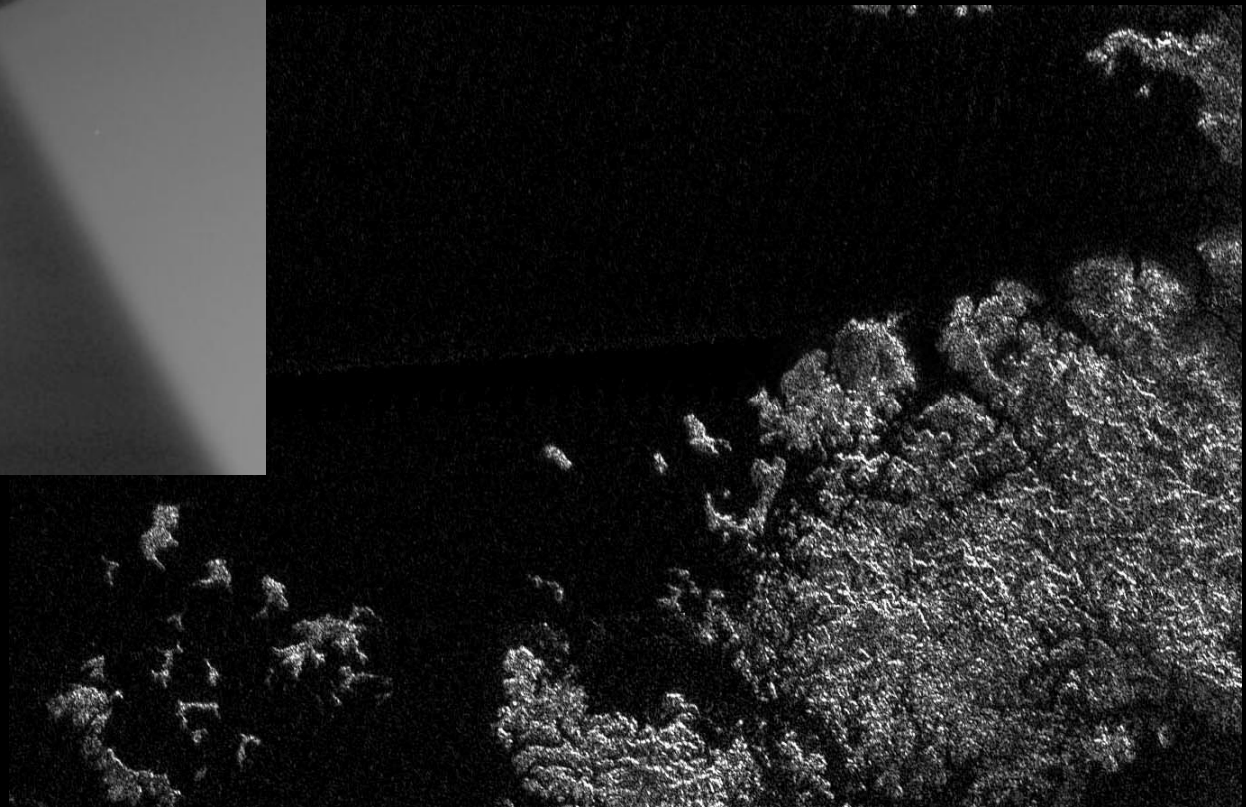
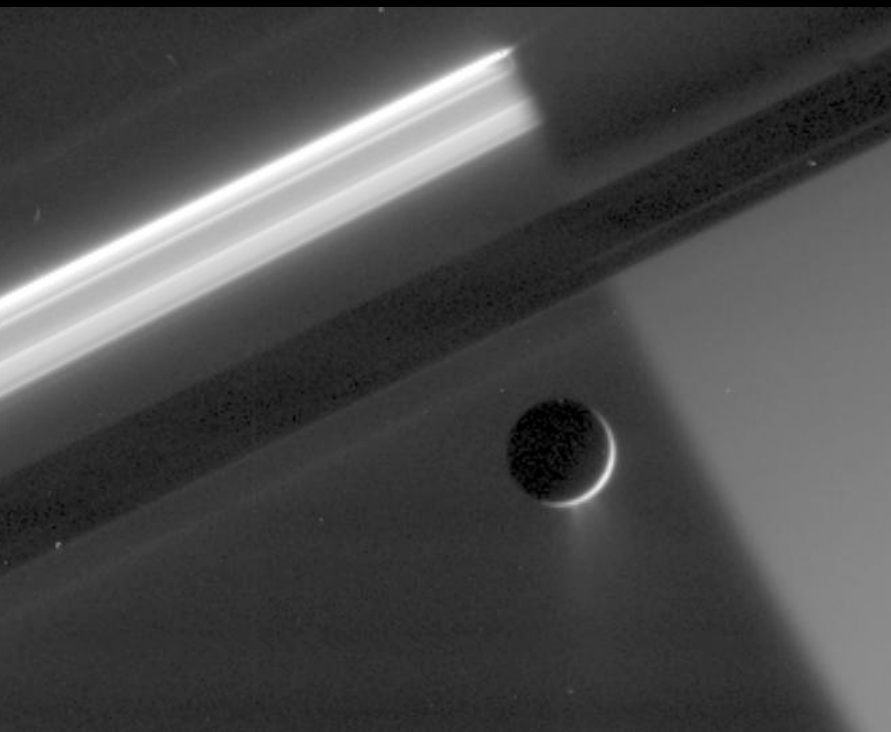
➤ *Understanding of SSE Decadal Survey Science versus Cost*

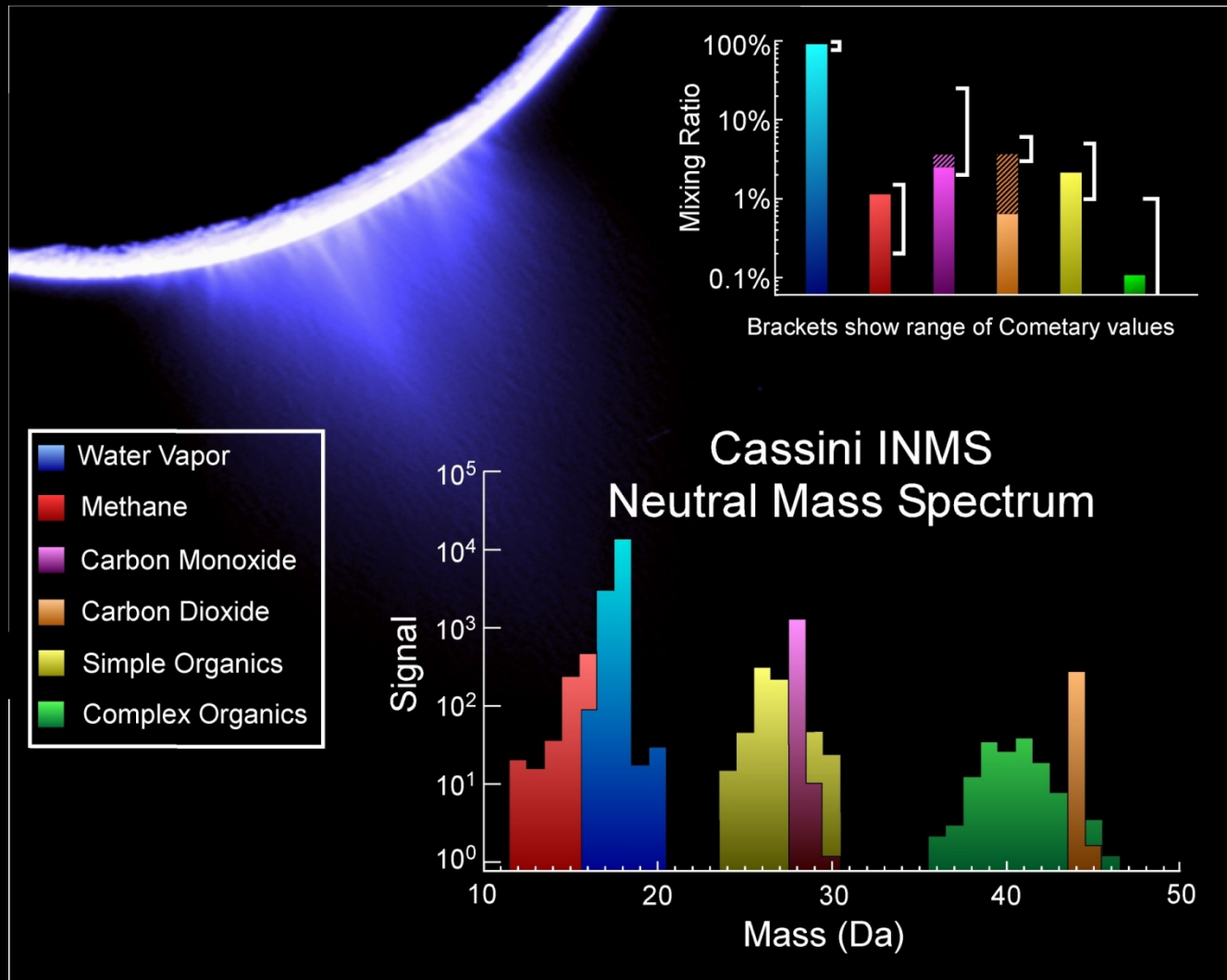


- **Propulsive Orbit Insertion (Non-Aerocapture)**
 - Shortest possible flight times
 - Opportunity for Saturn science and Enceladus flybys
- **Cost: \$2.1B (FY2007) Cap**
 - Strong budgetary preference for Atlas class LV and single launch
- **Level 1 Science: Titan, Saturn System, Enceladus**
 - Titan is the primary target; other targets as they inform us about Titan
- **RPS Availability: MMRTGs only for orbiter**
 - Study limit of 7 MMRTG worth of plutonium for entire mission
- **Accommodate *in situ* elements**
 - Provided by ESA; accommodation, RPS and Launcher provided by NASA
- **Launch Years 2016-2017**



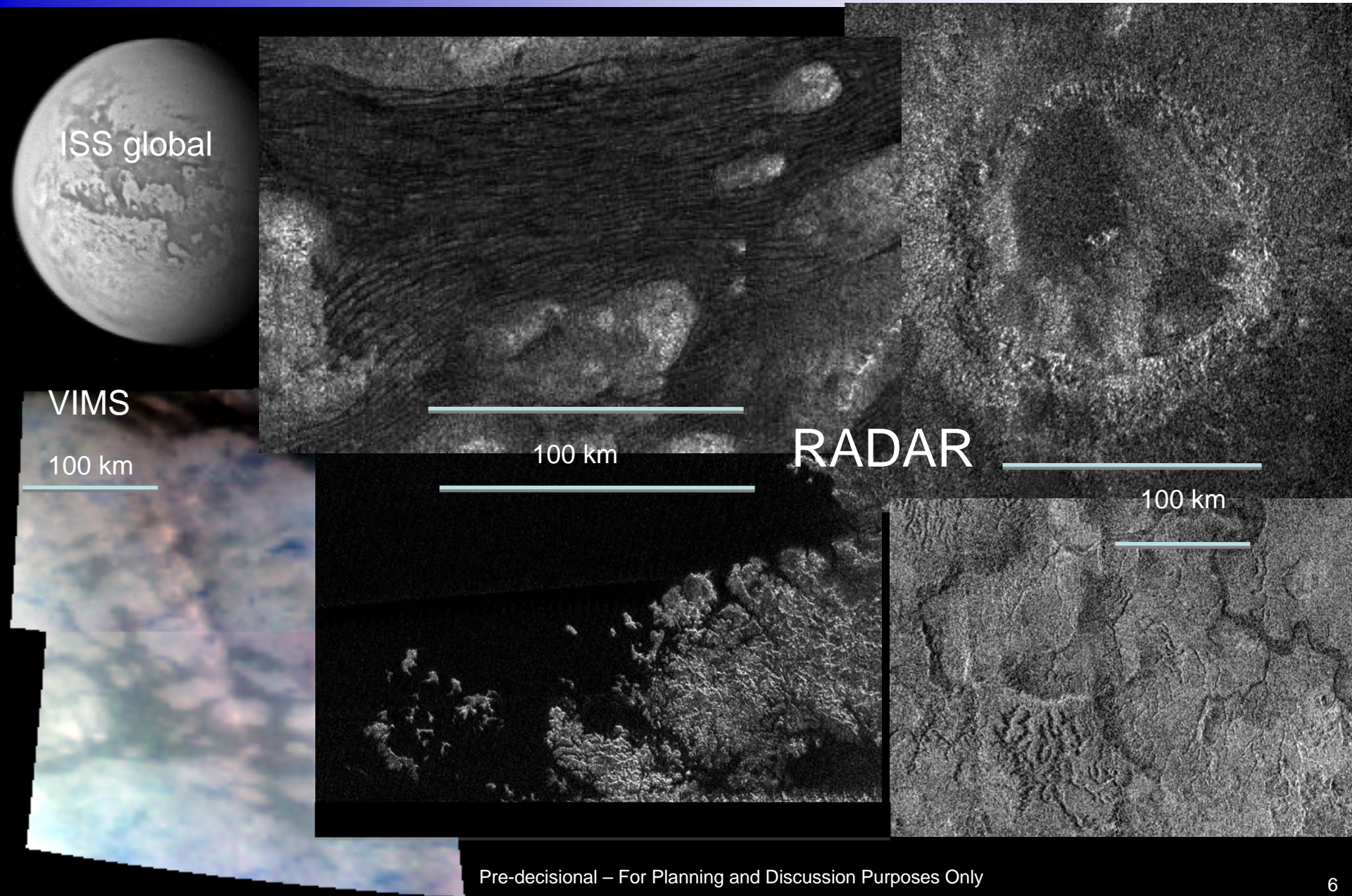
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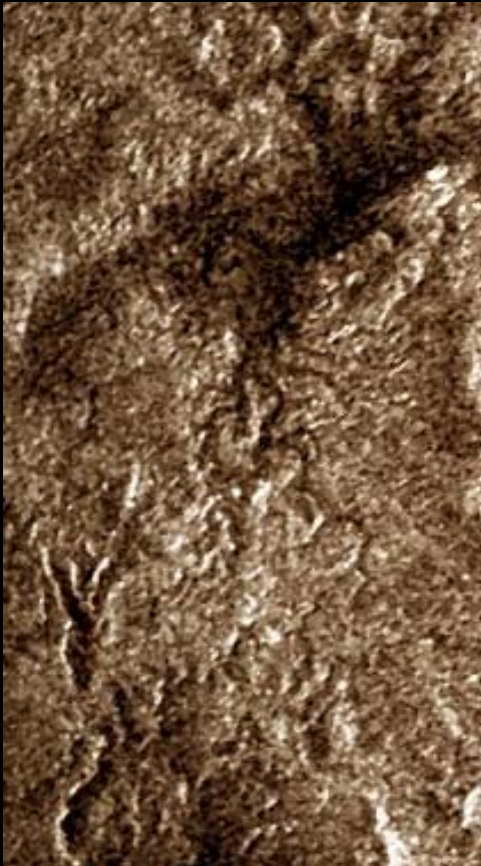






Titan from Saturn Orbit: Methane Cycle

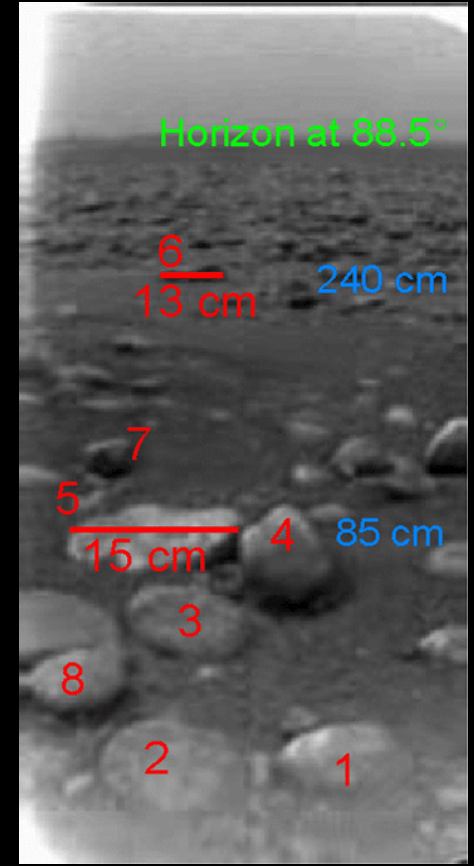




500 meter resolution
Broad fluvial channels
(Cassini Radar)



50 meter resolution
Small-scale sapping
(Huygens DISR)



5 cm resolution
Fluvial outflow
(Huygens DISR)

- **Goal A: Explore Titan, an Earth-Like System**
 - How does Titan function as a system? How are the similarities and differences with Earth, and other solar system bodies, a result of the interplay of the geology, hydrology, meteorology, and aeronomy present in the Titan system?
- **Goal B: Examine Titan's Organic Inventory - A Path to Prebiological Molecules**
 - What is the complexity of Titan's organic chemistry in the atmosphere, within its lakes, on its surface, and in its putative subsurface water ocean and how does this inventory differ from known abiotic organic material in meteorites and therefore contribute to our understanding of the origin of life in the Solar System?
- **Goal C: Explore Enceladus and Saturn's magnetosphere - clues to Titan's origin and evolution**
 - What is the exchange of energy and material with the Saturn magnetosphere and solar wind? What is the source of geysers on Enceladus? Does complex chemistry occur in the geyser source?



TSSM Planning Payload



Orbiter

6 instruments plus radio science

HiRIS - 1-6 micron hi-resolution imager and spectrometer

TiPRA - Radar sounder and altimeter

PMS - Polymer mass spectrometer dual port

SMS - Microwave spectral sounder

TIRS - Thermal Infrared Radiometer and Spectrometer

MAPP - Magnetometer and plasma package

RSA - Radio science to perform accelerometry (gravimetry)

¹Full Suite of in situ Elements (notional)

Lander

Chemical analyzer (with chiral discrimination)

Simple imager/photometer

Geophysics package (seismometer/magnetometer)

Montgolfiere Balloon

Multispectral imager/spectrometer

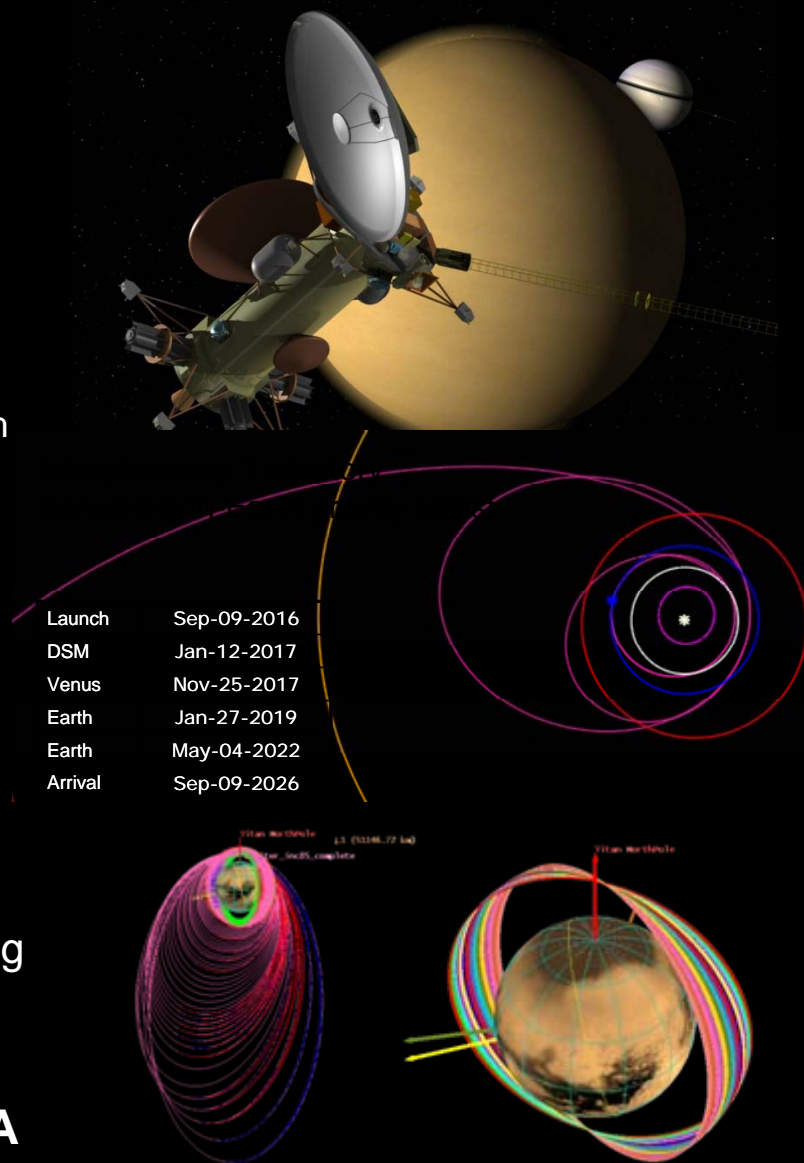
Tunable diode laser spectrometer/nephelometer

Magnetometer

Heavy ion (cosmic ray) detector

¹ESA CDF activities now underway

- **Objectives: Titan orbit, Saturn system and Enceladus**
- **Orbiter accommodates ESA-provided in situ elements;**
 - Core mission includes lander
 - Sweet-Spot and Enhanced missions include both lander and Montgolfiere but likely exceed study cost cap
- **Mission Timeline:**
 - Launch 9/2016
 - Saturn arrival 9/2026
 - Saturn Tour; includes 4 Enceladus and 15 Titan flybys
 - Dedicated Titan aerosampling and mapping orbit
- **Focused payload: 6 instruments + RSA**



- **NASA Titan Orbiter**
 - Would be launched in 2016-2017
 - Radioisotope powered
 - Would reach Saturn in ten years, spend 1.5 - 2 years in Saturn orbit
 - 4 Enceladus and ~15 Titan flybys before entering Titan orbit
 - Would conduct dedicated investigation of Titan and provide in situ accommodation
- **ESA In Situ Elements (Lander, Montgolfiere Balloon)**
 - Would be launched in 2016-2018 (depends on ESA launch availability)
 - Radioisotope powered; launched on NASA provided LV
 - Would reach Titan in ten years and spend one year at Titan in the lower atmosphere and on the surface -- potential for extended mission
 - Would conduct an intensive in situ investigation of Titan's lower atmosphere, surface and interior
- **Single Launch of orbiter and lander on Atlas V is Core - Other architectures enable full suite of in situ elements but exceed study cost cap (e.g., SEP, Two Launch)**

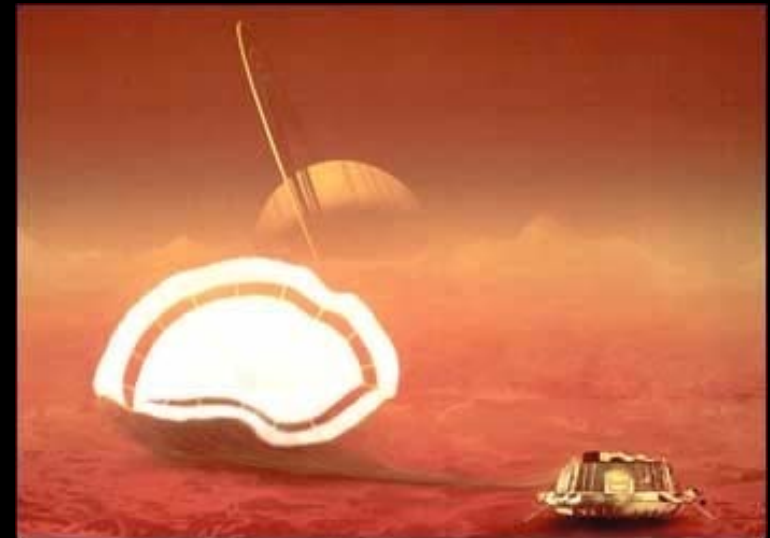
- **Montgolfiere Balloon**

- Release 4-6 months prior to arrival; <6km/s
- Near-equatorial to mid-latitude location
- Relay to orbiter and Direct to Earth (DTE) in Saturn tour; hi-rate relay after TOI
- Floats at 10km (+2 -8 km) altitude
- Circumnavigates the globe
- Lower atmosphere and surface science
- > 6 Earth months life (science requirement)

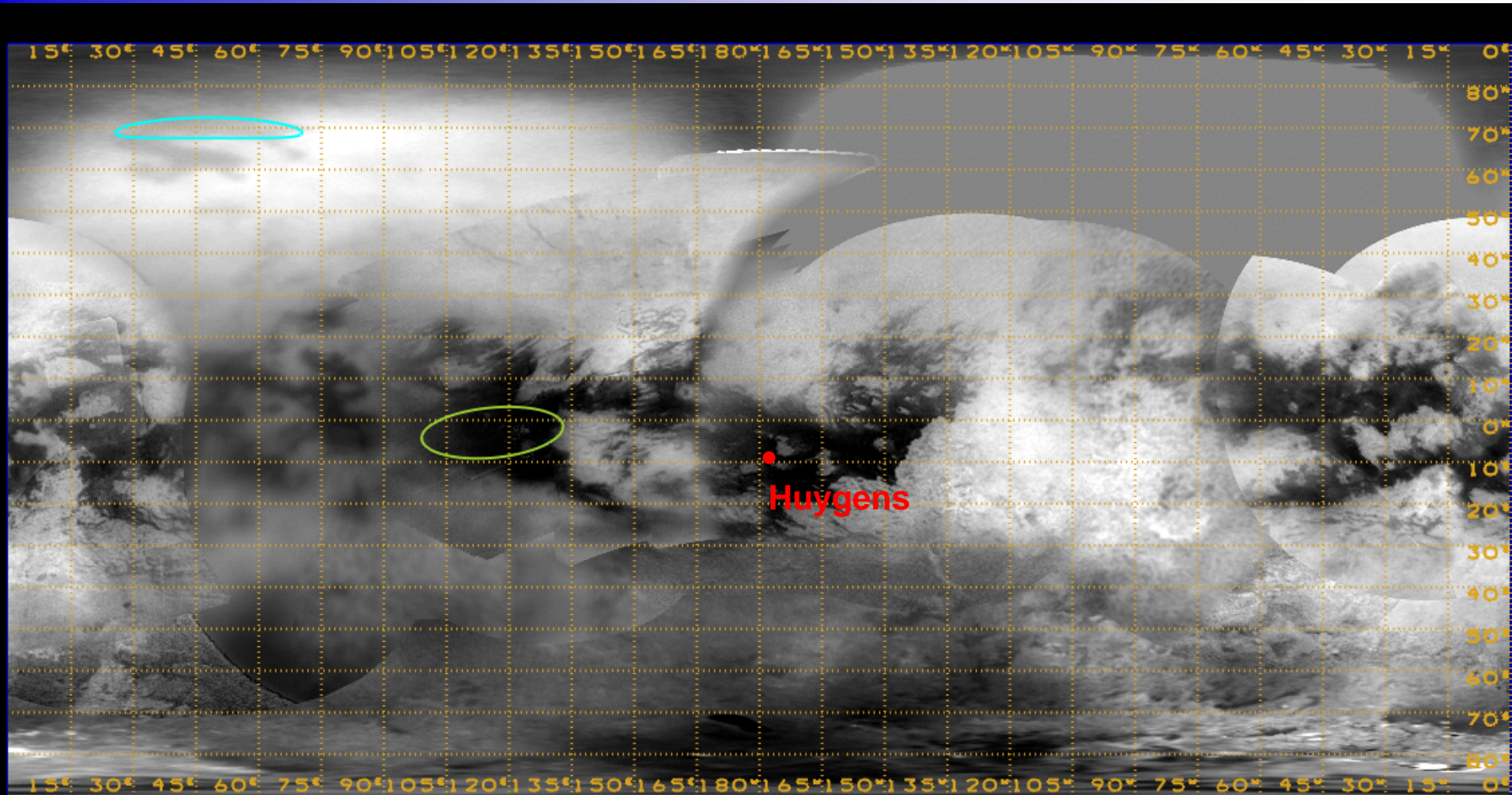


- **Capable Lander**

- Would land in lake or dry lake bed at northern latitudes, or mid latitude
- Entry conditions very similar to balloon's
- Relay options similar to balloon's
- Surface, hydrology and interior science
- >1 Earth month (2 Titan days) lifetime dry landing
 - >1 hour lake landing, battery power

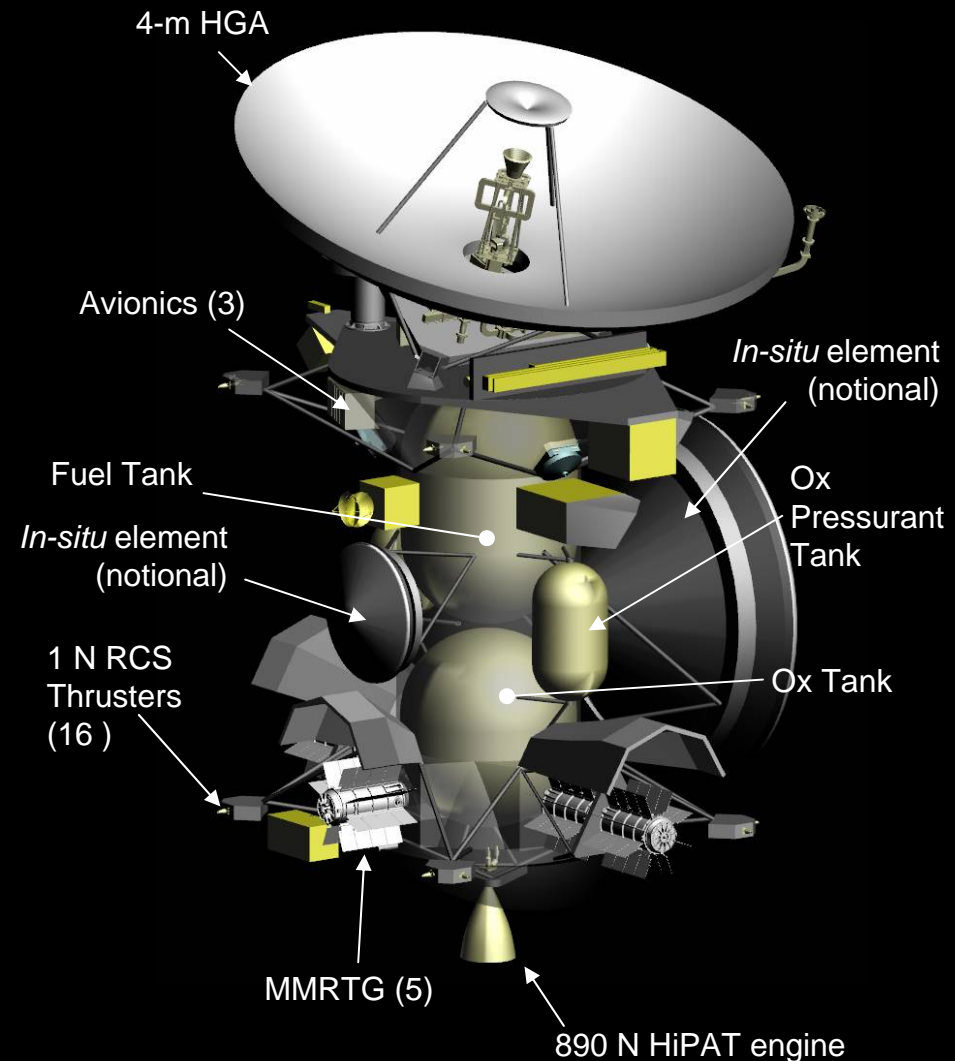


ESA CDF efforts underway to define in situ elements

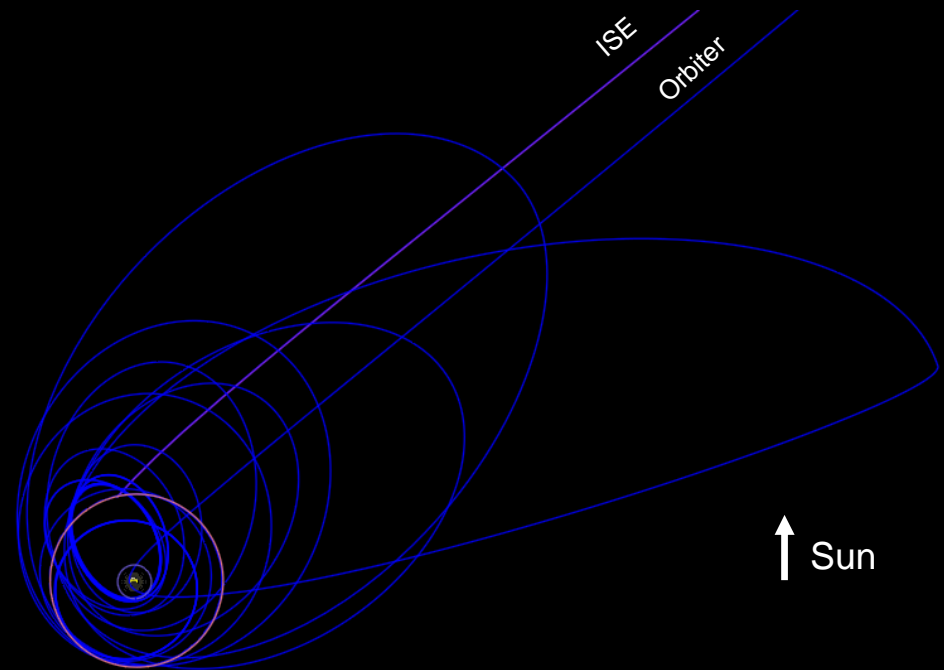


- Lander would be targeted to north polar region or mid-latitude
- Balloon would be targeted to mid-latitude region

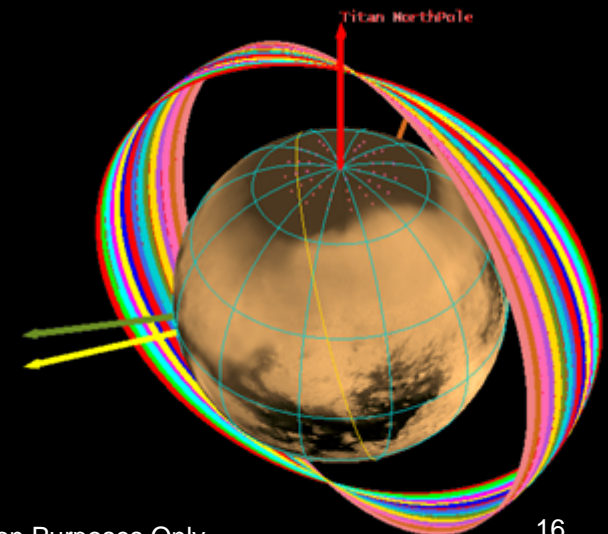
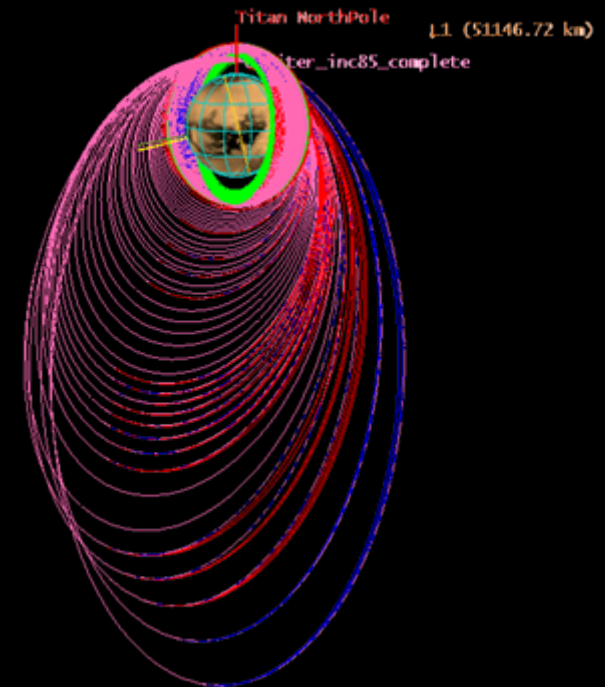
- Configuration represents balance of science, mass, cost, & risk
- Spacecraft dry mass ~1644 kg including 33% margin
 - 150 kg allocated to orbiter instruments
 - Current *in situ* mass capability delivered to Titan orbit ~150 kg
 - Capability 300 kg for pre-SOI release
 - ESA currently designing to 150 kg allocation
 - Orbiter structure designed to accommodate up to two *in situ* elements at ~600 kg total mass
- 75 kbps to DSN 34-m station
- Total Mission Dose estimated at ~20 krad (behind 100 mil Al)



- **1.9 year Saturn gravity-assist tour from Sep 8, 2026 to Aug 14, 2028 with 13 Titan flybys and 4 Enceladus flybys**
- **Tour Consists of Three Phases:**
 - **Initial Slow-Down**
 - 100 day transfer from SOI to first Titan flyby; reduces orbit energy to set up Enceladus flybys
 - **Enceladus Flybys**
 - 4 Enceladus flybys (100-400 km periapse altitude)
 - **Final Slow-Down**
 - Reduces Titan V_{∞} from 4 km/s to 0.9 km/s for efficient Titan orbit insertion

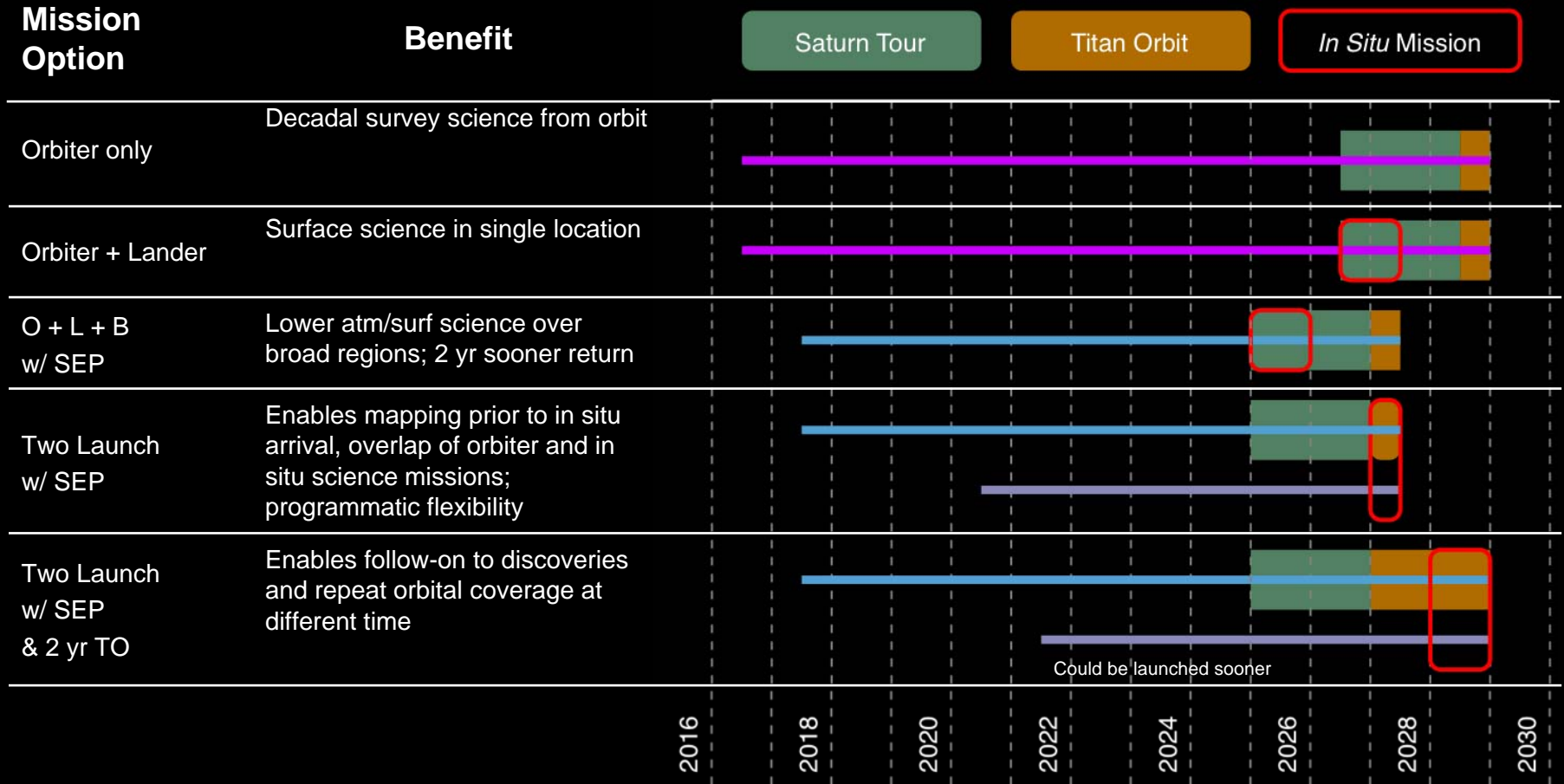


- Inserts into initial 750 km by 15,000 km ellipse
- Aerobraking reduces ellipse over two months while sampling atmosphere down to 600 km
 - ~170 passes
 - ~400 m/s delta-V savings
- Aerobraking phase is followed by a 6 month mapping phase
 - 1500 km circular orbit
 - Near-polar (85° inclination)
 - Orbit plane varies from ~4 pm to ~3 pm over a 6-month mapping period





Additional Mission Options



- **A mission to study Titan in depth, with visits to Enceladus, addresses key objectives in the 2003 Solar System Decadal Survey and questions raised by spectacular discoveries of Cassini-Huygens**
 - This mission study suggests a Titan orbiting mission is possible within the \$2.1B cap imposed on the study
 - A Titan orbiting mission that accommodates an ESA-provided lander is estimated to cost slightly more than the orbiter-only mission
 - Use of a SEP stage or implementation of a two-launch mission architecture would allow accommodation of both an ESA lander and Montgolfiere at a correspondingly higher cost
- **ESA would provide *in situ* elements at minimal accommodation costs to NASA; NASA provides RPS and launch**
- **Launch opportunities that deliver equal or greater mass to Titan available in most years; offers flexible mission timing**